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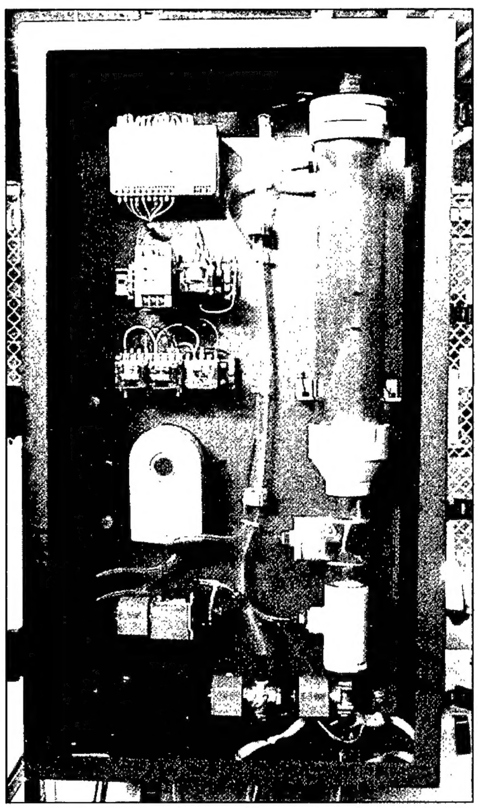
TECHNICAL REPORT
TR-2190-ENV

SENSOR TO DETECT AQUEOUS FILM FORMING FOAM (AFFF) IN SHIP BILGE WATER: CONSTRUCTION AND INSTALLATION



by

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This report presents detailed instructions on how to build, install, calibrate, and test a device that detects the presence of aqueous film forming foam (AFFF) in wastewater. The primary use of the sensor is the detection of AFFF in the bilge water of Navy ships. If AFFF is present in bilge water off-loaded to a shore-side wastewater treatment plant, it may cause serious upsets in treatment plant operation. Early detection of AFFF permits Navy base operating personnel to take measures to prevent AFFF from entering the wastewater treatment system.

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EXECUTIVE SUMMARY

This report presents detailed instructions on how to build, install, calibrate, and test a device that detects the presence of aqueous film forming foam (AFFF) in wastewater. The primary use of the sensor is the detection of AFFF in the bilge water of Navy ships. If AFFF is present in bilge water off-loaded to a shore-side wastewater treatment plant, it may cause serious upsets in treatment plant operation. Early detection of AFFF permits Navy base operating personnel to take measures to prevent AFFF from entering the wastewater treatment system.

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OBJECTIVE

The objective of this document is to provide the necessary information to procure, install, operate, and maintain a sensor system to detect the presence of aqueous film forming foam (AFFF) and other foam forming chemicals in wastewater streams. The sensor system consists of two assemblies: the AFFF sensor and an oil-water separator. The sensor measures the amount of foam forming chemicals in a sample of wastewater and sends out an alarm if the amount of foaming chemicals exceeds a preset value. The wastewater sample must be free of significant amounts of oil and dirt. An oil-water separator may be required at some installations to provide a clean wastewater sample to the sensor assembly.

SENSOR DESIGN

Parts List. A complete list of parts necessary to fabricate the AFFF sensor assembly is presented in Appendix A. Appendix A also includes a list of possible parts suppliers.

Computer Codes. A listing of the ladder logic diagram for the programmable logic controller (PLC) is presented in Appendix B. Appendix C presents the settings used for the recommended programmable ultrasonic range-measuring device.

OIL-WATER SEPARATOR DESIGN

Parts List. A complete list of parts necessary to fabricate a water filter and oil separator assembly is presented in Appendix D.

SENSOR ASSEMBLY

Mechanical. A photograph of the AFFF sensor is presented in Figure 1, and a general schematic of the device is presented in Figure 2. The mechanical parts of the AFFF sensor are assembled according to Figures 3 through 5. Figures 3 and 4 show how the various components are assembled. The sensor tube cap is fabricated from PVC plastic stock as illustrated in Figure 5. The cap holds the acoustic range sensor in place and provides a mechanism for distributing the wastewater sample around the periphery of the sample tube. Two O-rings around the periphery of the cap form a seal between the sensor tube and cap, and prevent air leakage from the top of the sample tube while the system is operating. Most cities have small machine shops and engineering prototype shops that can procure the necessary parts and assemble the AFFF sensor using the parts lists and drawings provided. Assembly is straightforward and requires approximately 24 labor hours.

Individual components including DIN rail brackets, hose clamps, sensor tube clamp, air pump, and optical sensor brackets are mounted to the PVC subpanel with self-tapping screws. Terminal strips mounted on the back of the sub-panel for electrical connections are secured using machine screws and nuts.

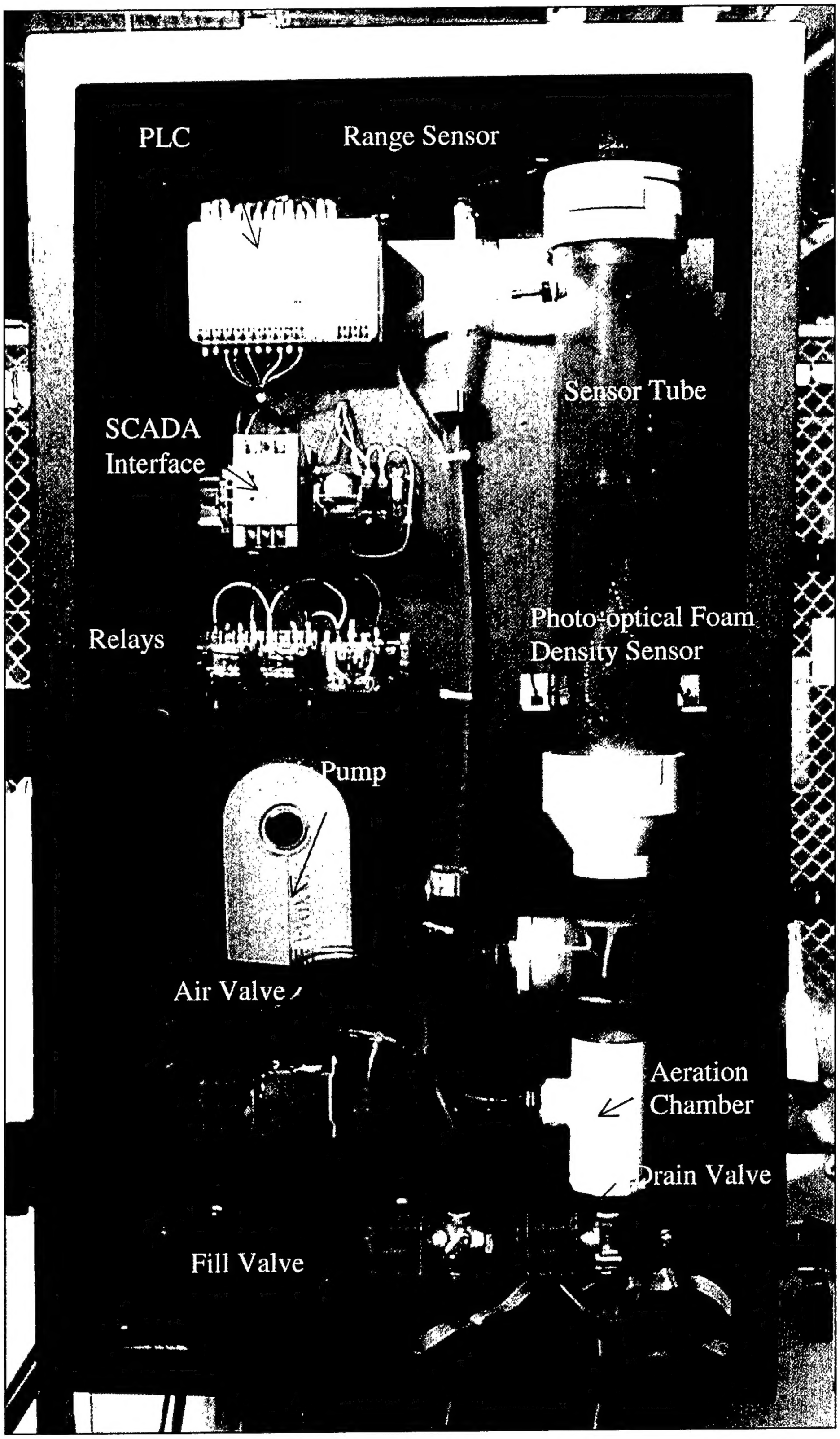

Figure 1. Photograph of AFFF sensor.

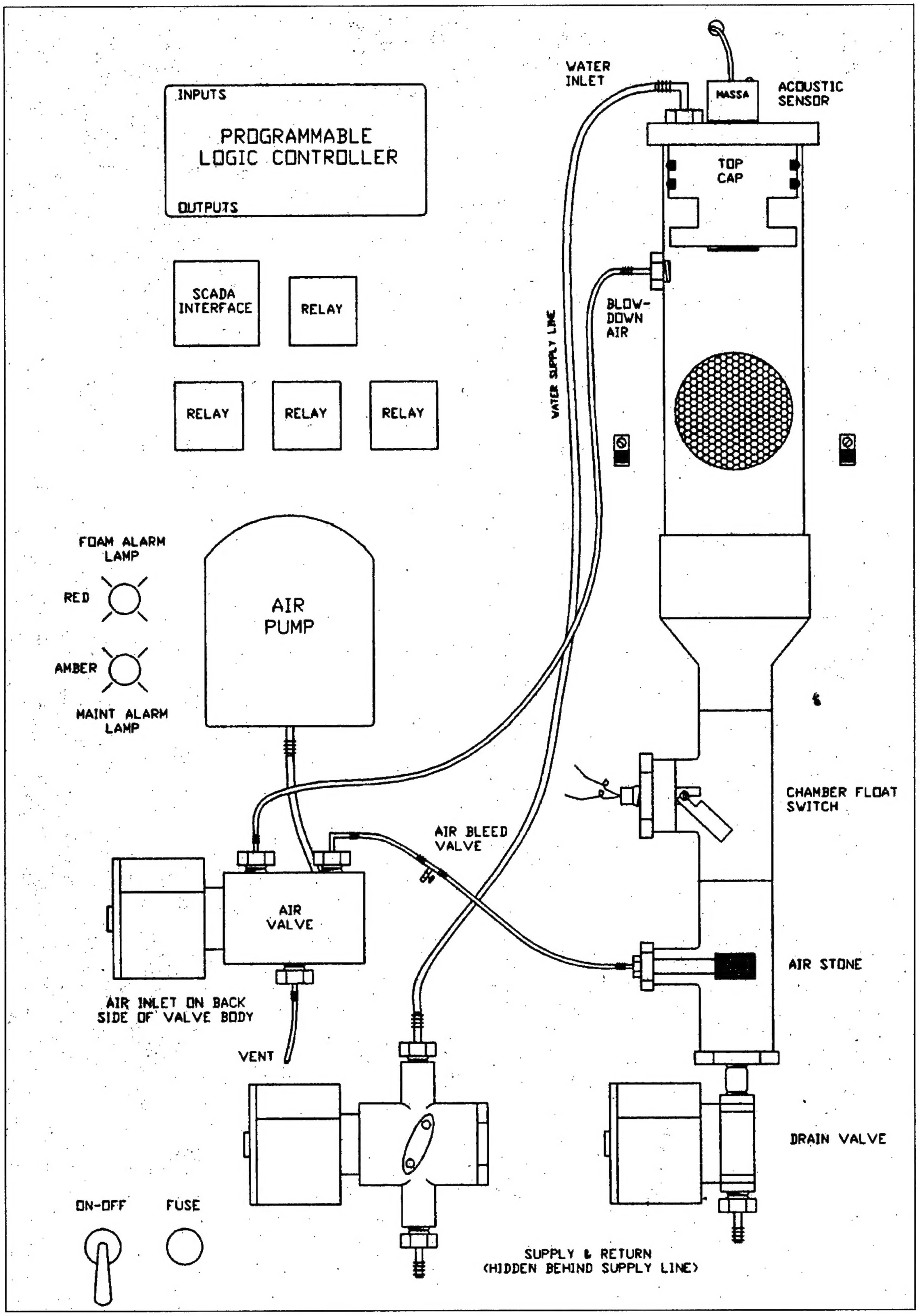

Figure 2. Schematic of complete AFFF sensor assembly.

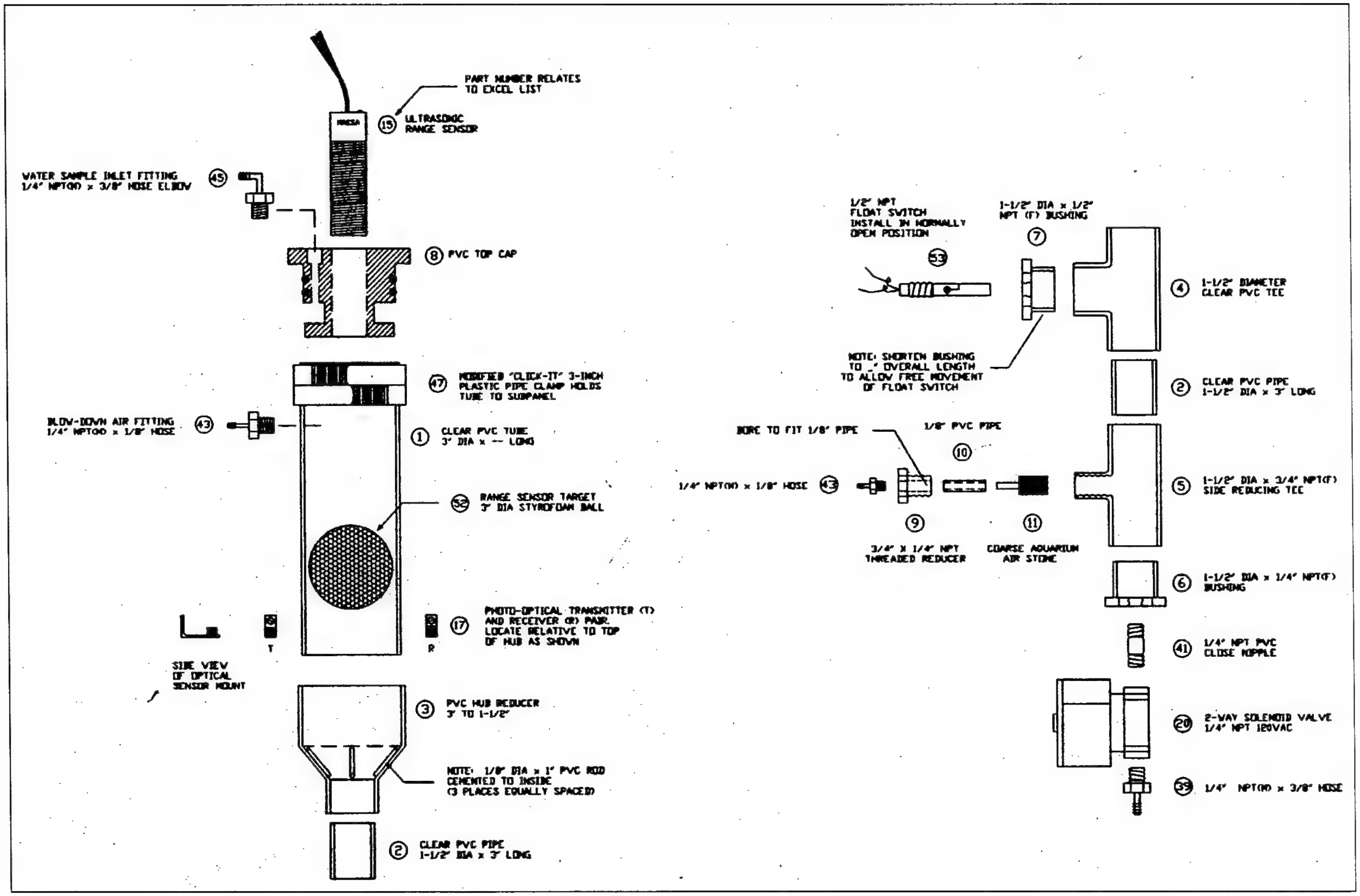

Figure 3 AFFF sensor components and component assembly

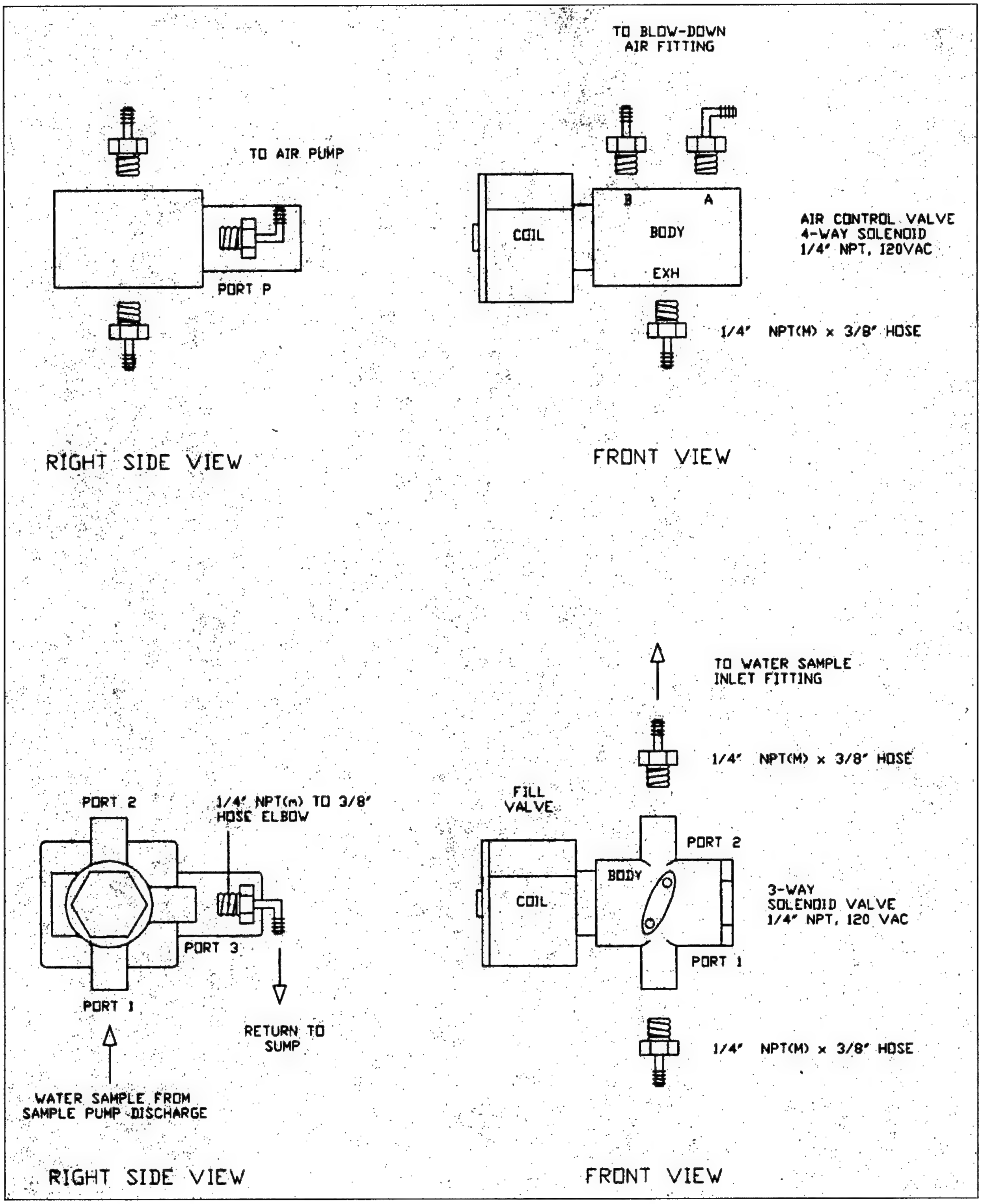

Figure 4. AFFF sensor valve assembly

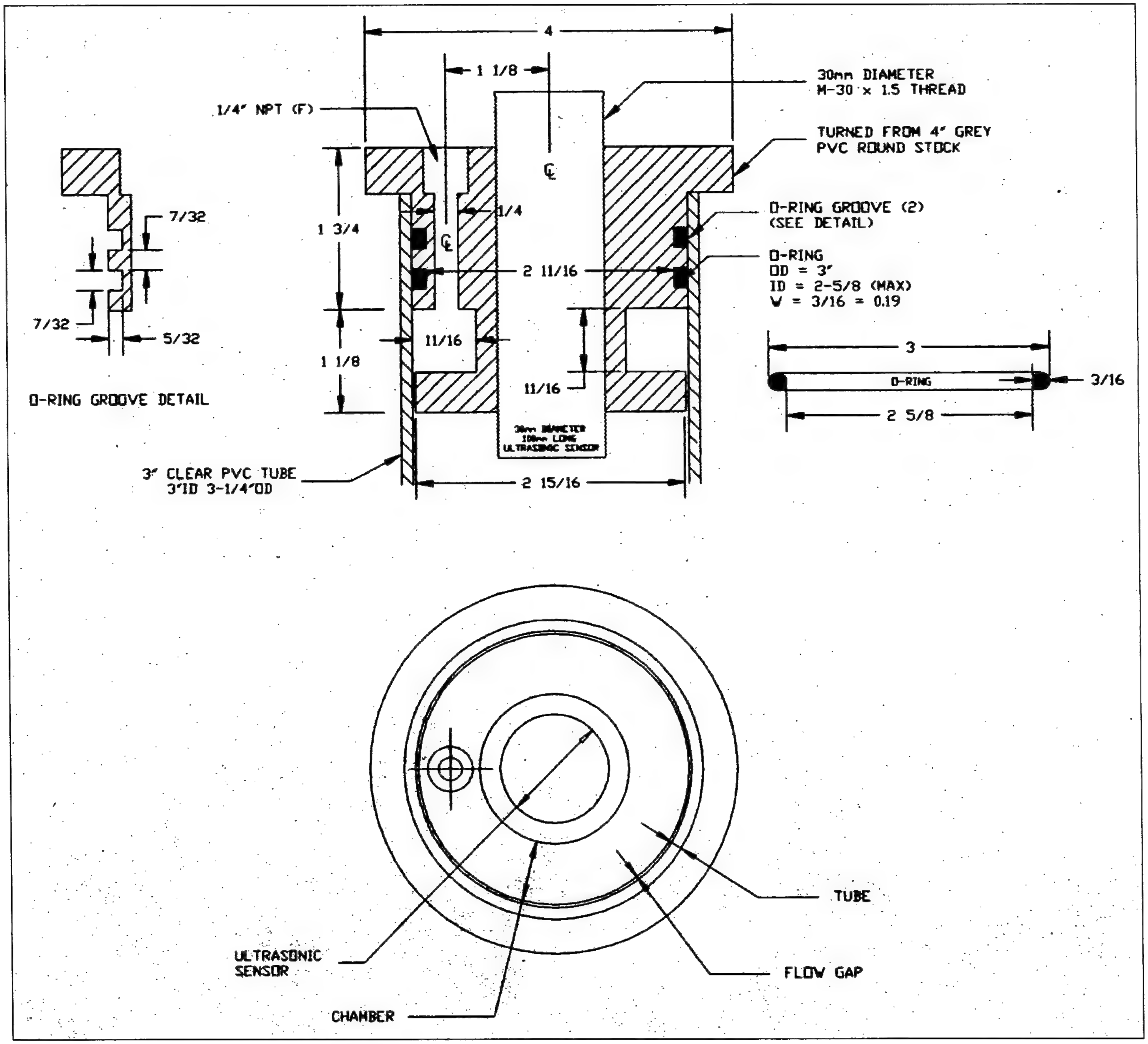

Figure 5. AFFF sensor tube cap.

Three solenoid valves that control the air supply, sample supply, and sample drain are also attached to the sub-panel. The solenoid valves are equipped with a ½-inch FPT connection on the solenoid coil for hard wiring. The valves are secured to the sub-panel by installing a ½-inch MPT close-nipple into the valve FPT connection and passing the tube through the panel and securing with standard ½-inch electrical conduit nuts on both sides of the panel. This not only securely holds the valve to the sub-panel but also allows electrical wiring to be passed to the back of the panel for electrical connection.

Two of the components used to construct the sensor assembly were modified from their original configuration. A portion of the 3-inch pipe clamp that secures the sensor tube to the sub-panel was removed to properly position the height of the tube above the sub-panel. The second component that was modified was the ½-inch to 1-1/2–inch slip PVC adapter used to mount the sample chamber float switch. The overall length of the fitting was shortened to allow proper movement of the float. Excess material from these parts can be machine cut or easily removed with a hacksaw and the parts cleaned up with a file.

Electrical. The electrical wiring diagram for the sensor is illustrated in Figure 6. Most of the wiring connections are made to terminal strips mounted on the back of the sub-panel. It is recommended that builders use terminal strips and color coded wiring to organize the wiring in a manner so as to minimize mistakes, allow for easier troubleshooting, and produce orderly professional looking results. It is also recommended that all wires be terminated with spade lugs. Lug connection should be both crimped and soldered to ensure proper connection and prevent wires from coming loose. One-inch riser blocks should be installed between the sub-panel and the back of the enclosure to provide adequate space for the wiring on the back of the sub-panel.

Programming. An IDEC, Inc., MICRO^3 Programmable Logic Controller (PLC) and a MassaSonic M-5000 Ultrasonic Sensor and their associated control software are key components of the AAAF sensor assembly. The PLC is programmed using *WIND*LDR software from IDEC, Inc. Both the *WIND*LDR and M-5000 software allow the user to monitor system performance. While in "monitor mode," *WIND*LDR software can be used to monitor the logic control program currently running in the PLC in "real time." Both of these programs provide the operator with valuable information as to how the system is functioning and where in the control sequence the system is.

Programmable Logic Controller. The PLC is programmed using *WIND*LDR software from IDEC, Inc. Follow the instructions in the manual supplied with the software and load the *WIND*LDR software onto the desired desktop or laptop computer. Copy the logic control program supplied with the sensor assembly to the attached computer. Using the *WIND*LDR software compile the program. The PLC programming process consists of connecting one end of the supplied cable to the PLC and the other end to the 9-pin, D-type serial port on the computer and downloading the control program following a short series of menu driven commands. Once the program has been downloaded to the PLC it will automatically run and continually loop through the program.

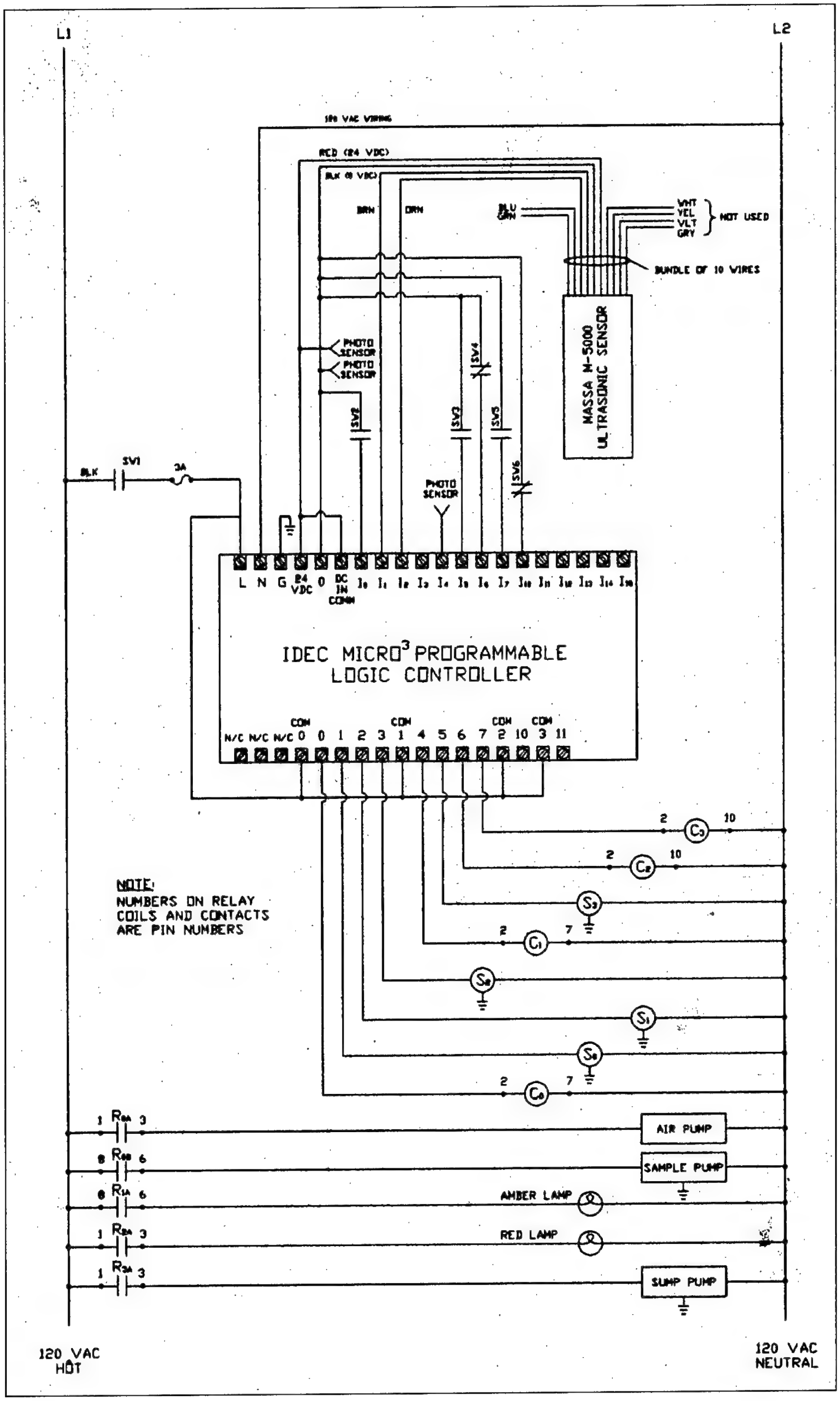

Figure 6. AFFF sensor electrical wiring diagram.

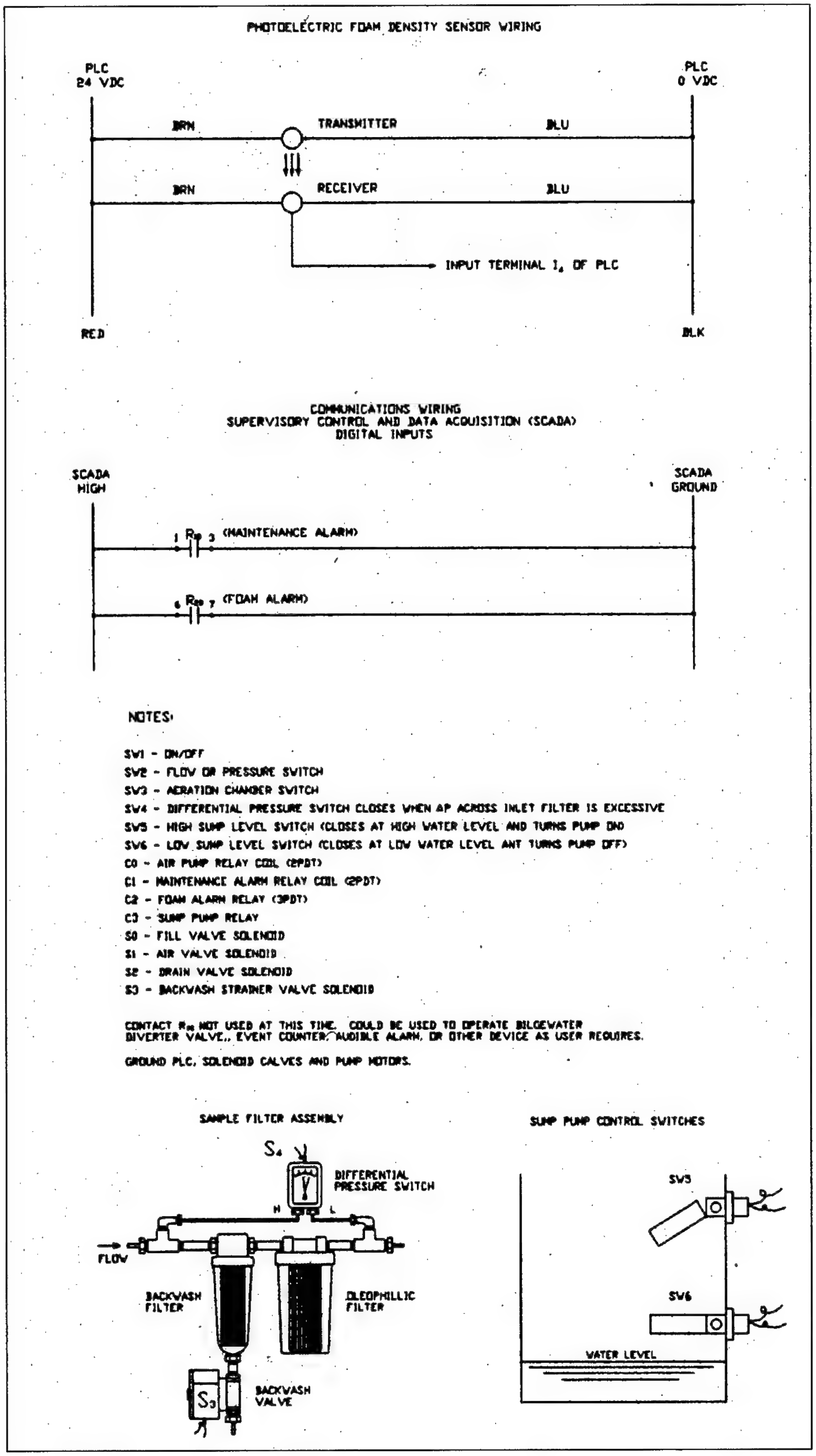

Figure 6. AFFF sensor electrical wiring diagram. (continued)

☞ *It is important that the user not modify the PLC program that is provided with the sensor assembly in any way. User modifications may result in damage to or improper operation of the sensor assembly.*

There is no need to reload the control program after power interruptions such as turning the unit "off" or after short power outages. Once programmed, the PLC memory will retain the program for approximately 30 days even if power to the PLC is removed. Power loss in excess of 30 days will result in program loss and require the PLC program to be reloaded.

Figure 7 is a screen-shot taken from the *WIND*LDR program in "monitor mode." Control items indicated in red are active.

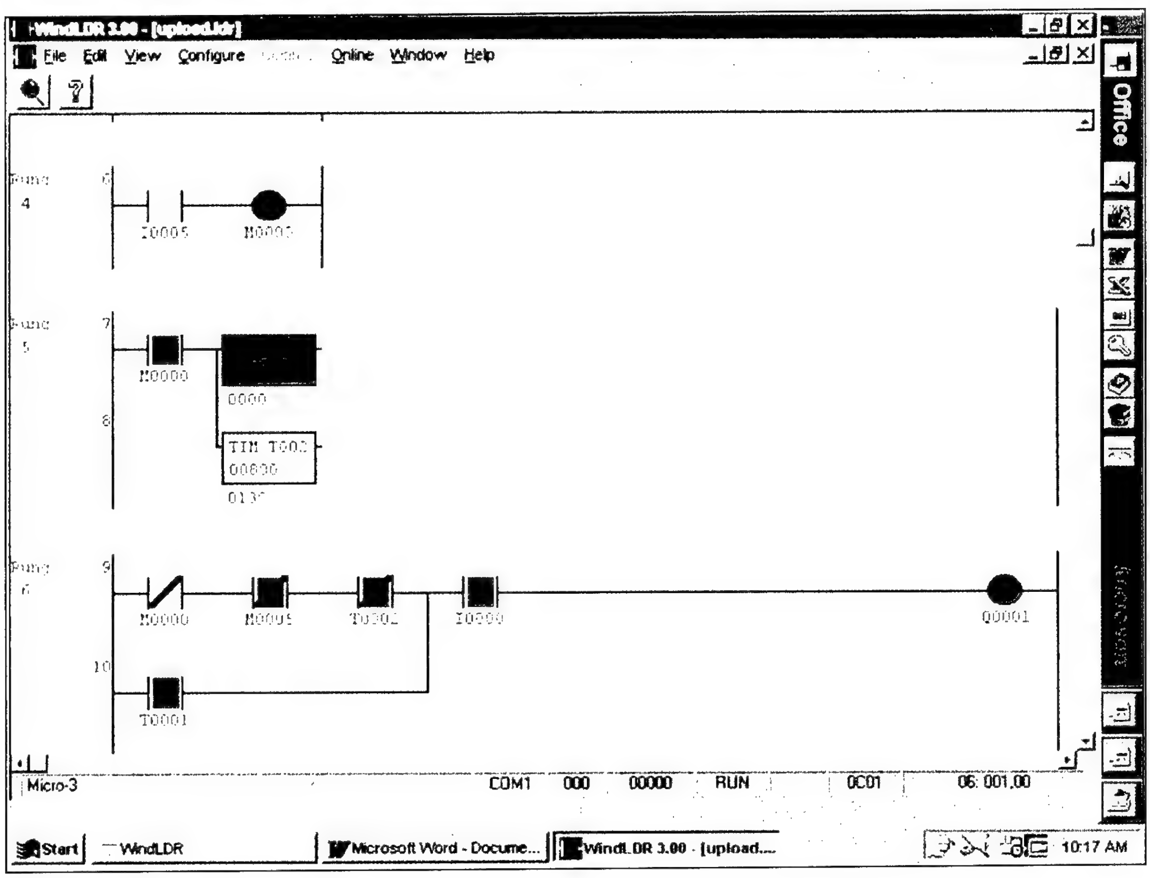

Figure 7. *WIND*LDR program in monitor mode.

Ultrasonic Range Sensor. The ultrasonic range sensor is programmed using the MassaSonic M-5000 software. Follow the instructions in the manual supplied with the software and load the M-5000 software onto a desktop or laptop computer. The programming process consists of connecting one end of the supplied cable to the 9-pin, D-type serial port on the computer, and connecting the other end to the supplied RS-232 to RS-485 communications

converter. The green wire from the M-5000/220 ultrasonic sensor is connected to terminal "A" of the communications converter and the blue wire is connected to terminal "B." For ease of access, the green and blue wires from the sensor are brought to the front of the sub-panel and connected to DIN rail mounted terminal blocks. With the computer properly connected to the sensor connections, open the M-5000 program and enter the sensor program data as shown in Appendix C.

The MassaSonic M-5000 software can also be used to monitor the performance of the ultrasonic range sensor in "real time." Figure 8 shows the computer screen of the MassaSonic M-5000 software in the "monitor mode." The M-5000 status panel indicates the "real time" distance from the ultrasonic sensor to the target. This screen also displays current loop output, set point output, echo status output, and sampling settings currently programmed into the sensor.

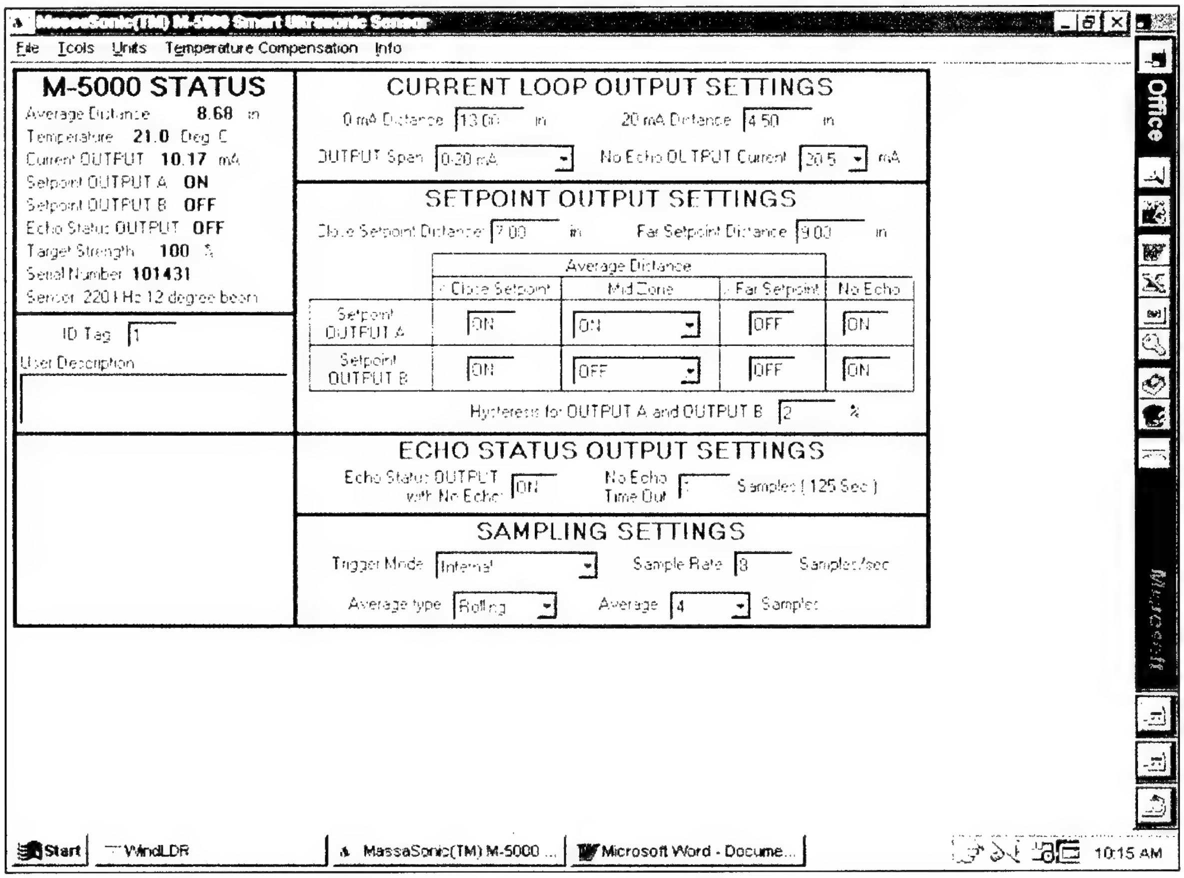

Figure 8. MassaSonic M-5000 software in monitor mode.

☞ *The non-volatile memory of the ultrasonic range sensor will retain the program if power is shut off. There is no need to reload the program after a power interruption.*

☞ *Once programmed, it is important that the user not adjust the position of the ultrasonic sensor. Subsequent adjustment may result in incorrect detection and reporting of foam events.*

OIL-WATER SEPARATOR ASSEMBLY

Mechanical. The oil-water separator is constructed according to the drawings presented in Figure 9. The oil-water separator uses a backwash strainer to remove larger particulate matter, and a filter equipped with an oleophilic element to remove oil. Periodically reversing the flow through the strainer ("backwashing") cleans the unit. The backwash interval and duration is controlled by the PLC in the AFFF sensor. As with all filters, the oleophilic element will eventually plug up and have to be replaced. A plugged filter will result in an increase in pressure drop across the filter. When this occurs, a differential pressure switch closes, telling the PLC that the filter is plugged and requires replacement. The AFFF sensor is designed to automatically shut down and alert the plant operators when the filter is plugged.

The oil-water separator described above is not suitable for locations were large amounts of oil are often found in bilge water. In these locations, a dynamic or centrifugal oil-water separator is required. A gravity type oil-water separator is not suitable for use with the foam sensor for several reasons. The large volume of water in the separator tank greatly increases the time required for the sensor to respond to changes in AFFF concentration. Also, the separator tank must be drained after each use to preclude false alarms being generated by the sensor.

It is very important that the AFFF sensor system have a representative sample of wastewater to measure, that is to say, a sample that accurately represents the waste being pumped to the treatment plant. If the sample is not representative, false alarms can be generated. For example, if the sensor system contains AFFF wastewater when the system shuts off, the sensor will detect AFFF again, on startup (and vice versa). The best way to prevent false alarms of this type would be to flush the complete AFFF sensor system with clean water each time the system shuts down. This approach is not practical in most applications. Rather than flushing the system with clean water after shutdown, the system is designed to flow wastewater through the sensor system for several minutes before aerating the sample and making foam height measurements. This assures that any wastewater that remains in the system plumbing from previous tests will not produce a false alarm.

Electrical. Power for the sump pump and backwash valve is switched on and off by the PLC in the AFFF sensor. Connect the pump to the appropriate terminal on the controller. Make all wire splices water-tight or locate them where they cannot get wet. Use the same precautions described above when making connections to the flow and level switches. Follow local electrical codes when wiring the pumps and switches. It is recommended that wires that can be electrically energized be enclosed in conduit.

Complete Assembly. A drawing of the complete sensor system is presented in Figure 10.

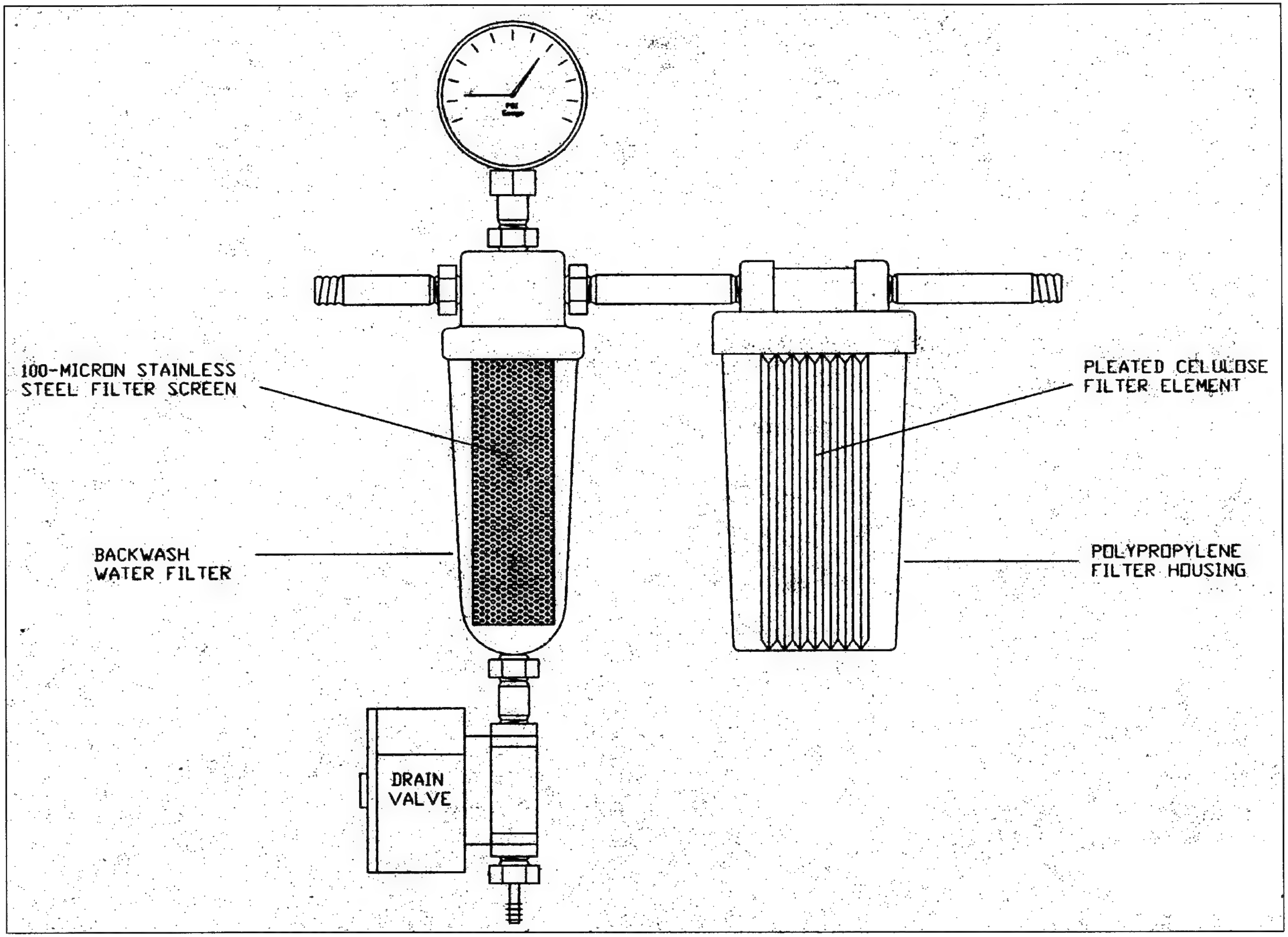

Figure 9. Oil-water separator

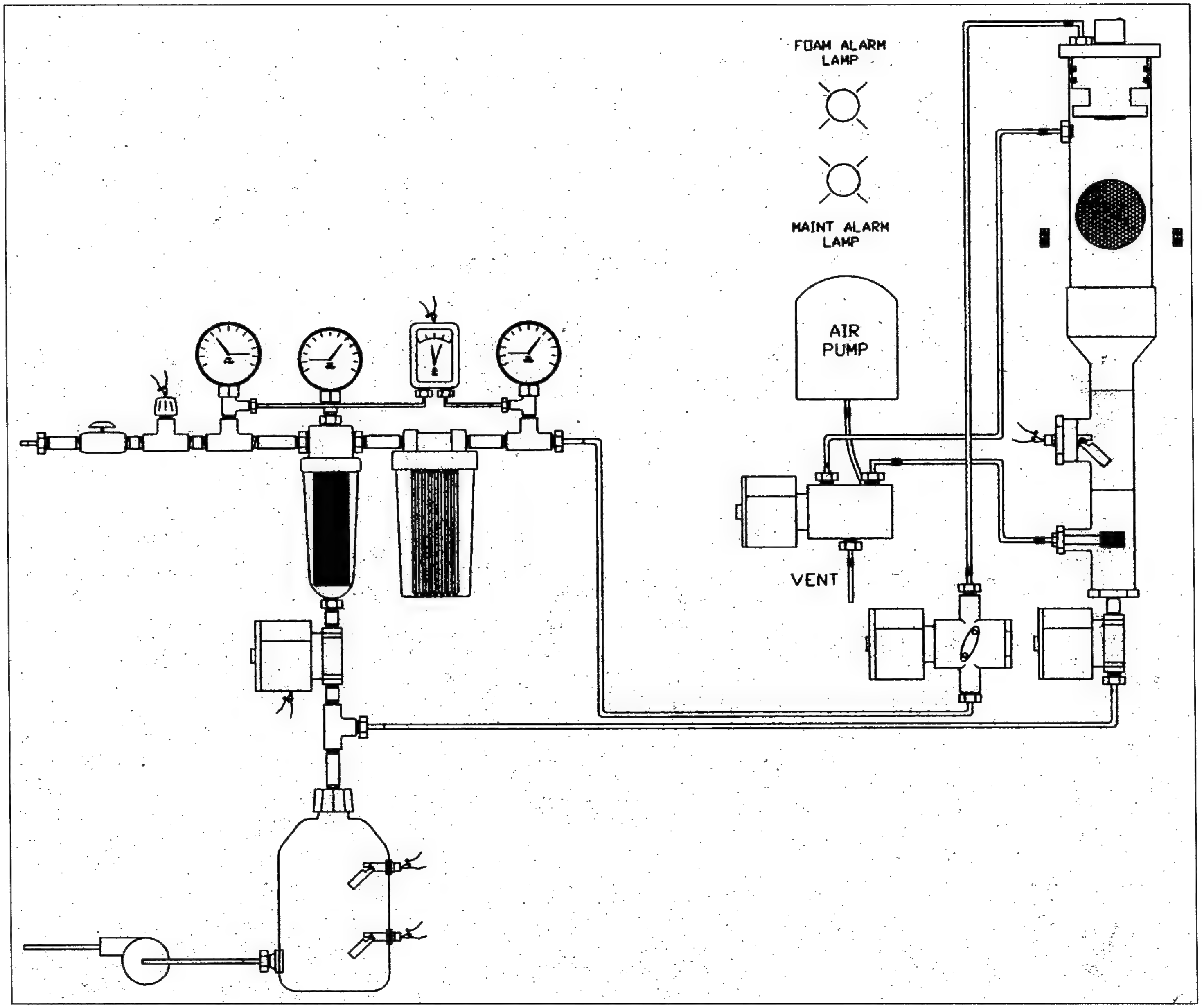

Figure 10. Complete oil-water separator assembly

FIELD INSTALLATION

A schematic diagram of a field installation is shown in Figure 11. A field installation is located at a pier bilge water lift pump station. These are the preferred locations for the AFFF sensor because they give the maximum warning of the presence of AFFF in wastewater input lines.

The field plumbing consists of piping to carry a sample of wastewater to the AFFF sensor unit and piping to carry the sample from the sensor to an approved drain.

In some locations, it may be possible to drain the AFFF sensor by gravity to an approved drain. However, in other locations elevation differences between the AFFF sensor and the drain may make it difficult to quickly drain the sensor by gravity. In these situations, the AFFF sensor drains directly into a small plastic container. A small pump periodically pumps the contents of the container to the drain. The pump is turned on and off by a pair of liquid level switches located in a container.

The design sample flow rate through the AFFF sensor is approximately 0.3 gallon per minute.

The electrical enclosure housing the AFFF sensor should be mounted on a wall or post as close to the wastewater sampling location as practical.

The AFFF sensor and sump pump are connected to a grounded electrical outlet. A GFCI outlet may be required by local building codes.

The supervisory control and data acquisition (SCADA) system reports the presence of AFFF foam in the wastewater to a central monitoring facility, such as the wastewater treatment plant or Navy Public Works office. The monitoring facility has the responsibility to respond to the alarm and take the required action. The action might include diverting the wastewater flow to a separate treatment system or holding tank, or stopping the ship from further pumping until a tank truck arrives to receive the contaminated bilge water. Two pair of wires connect the sensor to the SCADA system. The connections are to two digital input channels of the SCADA. One channel is the high foam alarm; the other is the maintenance alarm. If a SCADA system is not available, contact the Naval Facilities Engineering Service Center (NFESC) for alternatives.

NFESC has developed a small, inexpensive sensor status communications device to use if a SCADA system in not available at a facility. The device is pictured in Figure 12. The device continuously polls the status of the AFFF sensor. When foam is detected (or maintenance is required) the device automatically places a telephone call to a monitoring location. The monitor may be a computer terminal, pager, or web site. When the monitoring location answers the call, the device automatically transmits a message then hangs up the phone. Figure 13 show a computer screen from the monitoring location with a typical message. Each foam sensor installation would have its own unique identifying code, such as building number.

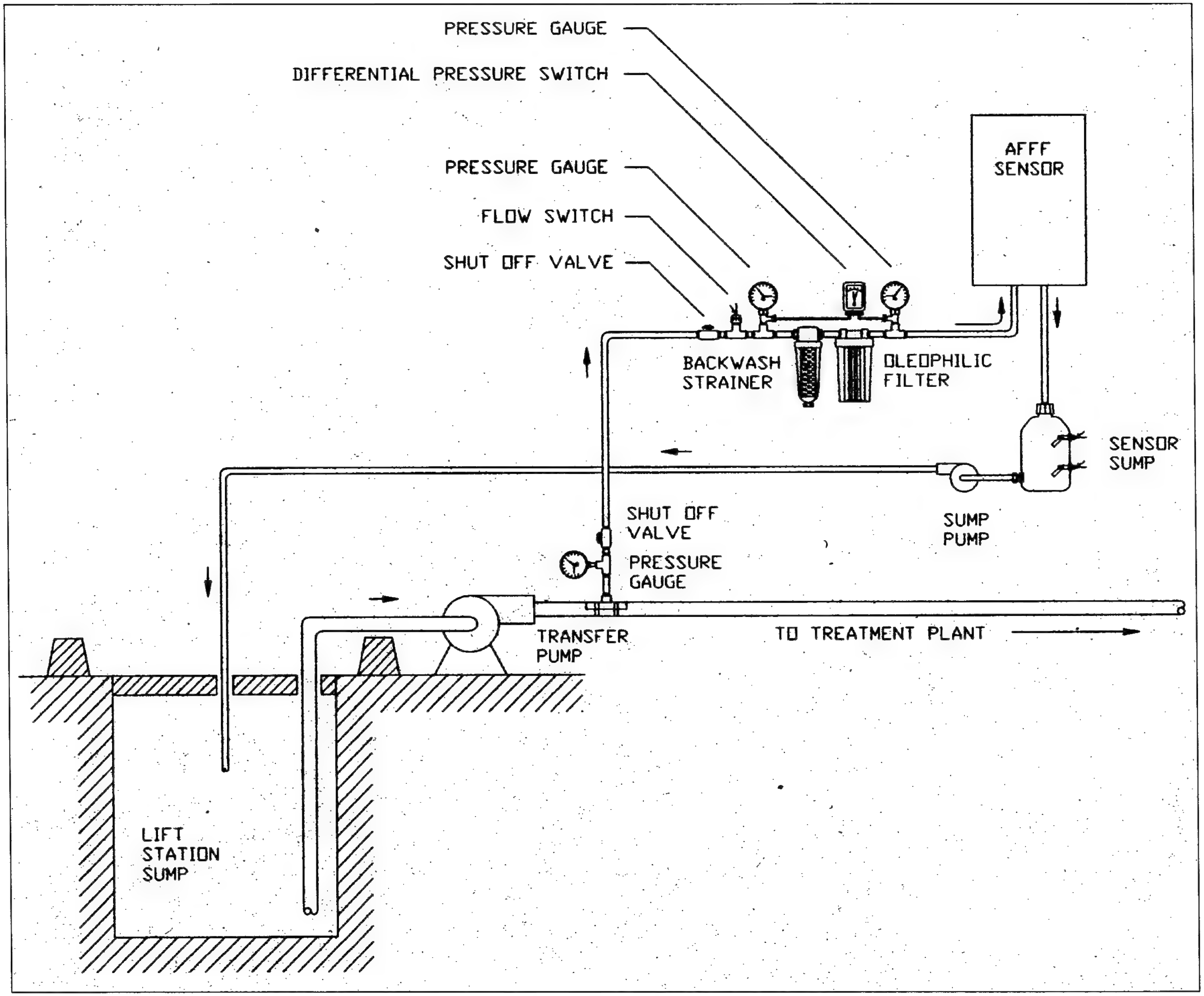

Figure 11. AFFF sensor field installation schematic

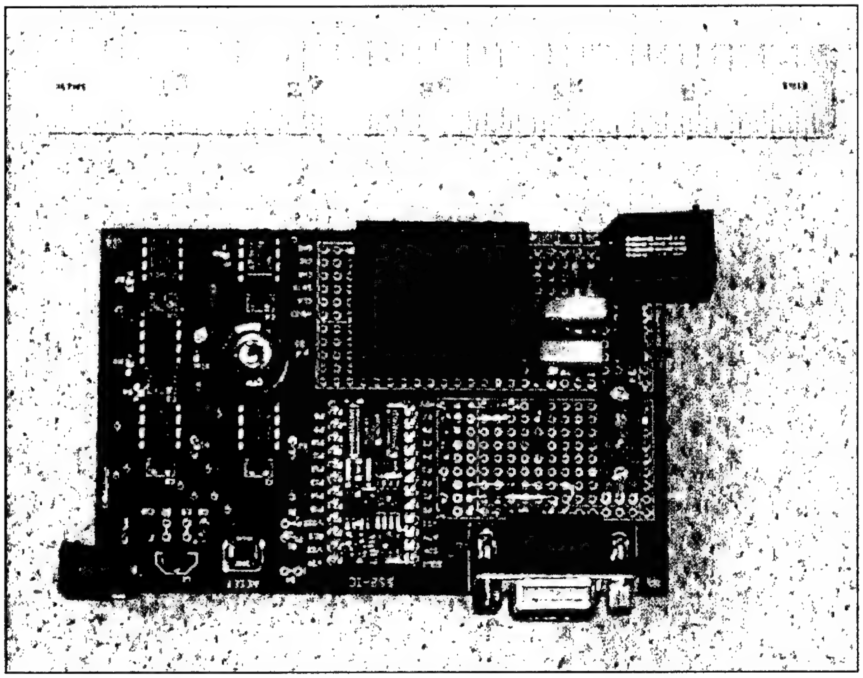

Figure 12. Communications adapter.

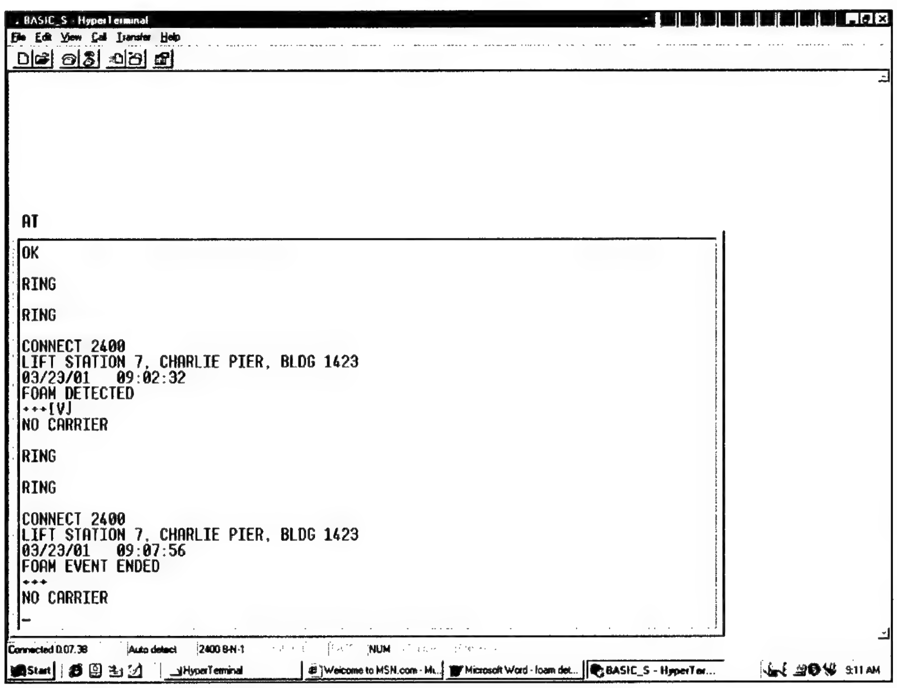

Figure 13. Computer monitor screen showing messages from AFFF sensor.

CALIBRATION

There are several ways to calibrate the response of the AFFF sensor, but for the sake of simplicity, only the most convenient and straightforward method will be presented here. A small valve is provided in the air supply tube that leads from the air pump to the aeration stone in the aeration chamber. If this "air bypass valve" is opened all the way, no air flows to the aeration stone and no foam is produced, regardless of the concentration of AFFF in the water. When the air bypass valve is completely closed, the maximum volume of air flows to the aeration stone. Under conditions of maximum aeration, the AFFF sensor (as configured with a known sample volume, aeration duration, and float weight) can detect AFFF at a concentration of about 15 parts per million.

The calibration process is as follows:

1. Shut off the wastewater supply.

2. Empty the sump container. Using a length of 3/8-inch diameter plastic tubing, temporarily connect the discharge of the sump pump to the inlet of the AFFF sensor. This will permit AFFF calibration solution to circulate from the sump tank through the AFFF sensor and back to the sump.

3. Open the air by-pass valve all the way.

4. Full strength 3% AFFF concentrate is 30,000 ppm active ingredients. Table 1 presents data for calculating other AFFF concentrations. Concentration numbers are expressed as ppm concentration of the active ingredients in AFFF.

Table 1. Data for Calculating AFFF Concentrations

AFFF Concentrate (ml)	Water (ml)	Total (ml)	Concentration (ppm)
1,000	0	1,000	30,000
100	900	1,000	3,000
10	990	1,000	300
1	999	1,000	30

Any concentration can be calculated using simple proportions. For example, to prepare a solution of 50 ppm concentration, measure out 50/30 x 1 = 1.67 ml of 3% AFFF concentrate and add water to bring the total volume to 1,000 ml, or 1 liter. To make 6 liters of 50 ppm solution, measure 1.67 ml x 6 = 10 ml of 3 % AFFF concentrate and add water to make 6 liters.

5. Fill the sump container with AFFF solution of the desired minimum concentration you wish to detect. The sump container must be filled to the level of the upper float switch for the pump to start.

6. Start the sensor by closing the flow switch. This can be easily done by connecting a jumper wire across the two wires coming out of the flow switch.

7. Slowly close the air bypass valve in a stepwise manner. That is to say, close the valve slightly and let the sensor go through at lease one fill-aerate-drain cycle. Observe the amount of foam produced. At first, a small amount of foam will be produced. Repeat the process, gradually closing the air bypass valve a little each sampling cycle until the foam alarm is triggered (the red light on the panel front will come on). The unit is now calibrated to detect the desired concentration (or greater) of AFFF.

8. Stop the sensor by opening the flow switch. Let the foam alarm timer expire (this will take approximately 3 minutes). After the timer expires, close the flow switch again and observe the action of the AFFF sensor. The sensor should detect the desired AFFF concentration during the fill-aerate-drain cycle. If not, repeat steps 6 and 7 to fine tune the adjustment.

SEQUENCE OF EVENTS

While the sensor system is operating many different things occur. Relays, valves, and lights turn on and off and foam is generated and washed from the sensor tube. The significance of these events can be confusing to the user. The sequence of events during normal operation of the sensor system is described below.

1. Bilge water is pumped from a ship to the oily-waste lift station. *Assume for this example that the wastewater contains 50-ppm AFFF.* As the sump in the lift station fills, large wastewater transfer pumps are energized to move the wastewater from the collection point to the wastewater treatment plant.

2. A small portion of this waste stream is diverted to the AFFF sensor. The flow-sensing switch installed in the oil/water separator signals the sensor unit to begin the wastewater sampling process.

3. The PLC continuously loops through its set of instructions. Therefore, it is not necessarily at the beginning of the program cycle when the system receives the signal from the flow switch. *However, for this example we will assume the system starts at the beginning of the fill cycle.*

4. With the fill valve energized, flow is directed to the top of the sensor tube. The sample flows into the cap on the top of the sensor tube and runs down the wall of the sensor tube. Water fills the chamber at the bottom of the sample tube until the float switch in the chamber closes. When the chamber is full, fill valve is de-energized and the wastewater flow is bypassed to the sump.

5. After an initial delay (to flush the pipes of the previous batch of wastewater), the air pump is activated and air flows through the air valve to the aeration chamber.

6. Aeration occurs for a predetermined length of time and foam is generated in the sensor tube.

7. As the foam rises in the sensor tube it lifts a polystyrene ball. The ball provides a firm target for the ultrasonic range sensor. The ultrasonic sensor mounted in the top cap measures the distance to the target. *(Because the wastewater sample contains 50 ppm AFFF, sufficient foam will be generated in the column for the target to reach the sensor set point.)*

8. As the target rises in the sensor tube, the beam of light between a pair of opposed photo-optical sensors is broken. As the target passes the beam, the beam then encounters the foam in the column. If the foam is of sufficient density that it continues to interrupt the light beam (and it continues to lift the ball to a lower set point programmed into the ultrasonic sensor), a red indicator lamp on the sub-panel is illuminated. *If the foam density is insufficient to block the beam from the optical sensors, the red lamp does not illuminate and the system recognizes that the AFFF concentration is below the pre-determined threshold.* When the red lamp is illuminated it indicates that the sample solution contains AFFF at or above a pre-determined threshold and the sensor system automatically sends a message to alert the plant operators.

9. *As soon as the red lamp is illuminated an internal timer in the control program begins to count down. The target must reach the lower set point during the next sample cycle before the timer expires or the lamp will go out.* If the ball continues to rise to a second "high alarm" programmed into the ultrasonic sensor, air is diverted from the aeration chamber to the top of the sensor tube. This prevents the target and foam from rising further and contacting the ultrasonic sensor.

10. After a pre-determined length of time, the sensor system enters a wash-down cycle. The drain valve is opened, sample flow is redirected to the top of the sensor tube, and air is redirected from the aeration chamber to the top of the sensor tube. The sample is flushed out the drain valve in the bottom of the aeration chamber and flows into the sump. Air pressure in the top of the chamber helps expel the sample from the sensor.

11. When the wash-down cycle is finished, the drain valve closes and a new wastewater sample fills the sample chamber.

12. Steps 5 through 10 are repeated until the sample no longer contains a high enough concentration of AFFF in the wastewater to cause the target to reach the low set point before the internal timer expires. When this occurs, the red lamp is extinguished. A message is sent by the SCADA system that the "foam event" has ended. Steps 5 through 10 will also stop when the flow switch signals the AFFF sensor system that

flow is no longer present in the wastewater transfer pump discharge line. When this occurs, the sensor assembly is automatically switched off.

MAINTENANCE

The AFFF sensor does not require routine maintenance. However, two conditions will cause the sensor to send a maintenance alert to the plant operator (via the SCADA). These two conditions are: a restricted filter system or an obscured optical sensor path. When either of these conditions occurs, the amber light on the sub-panel will also be illuminated.

Restricted filter: This is due to a plugged strainer or oleophilic filter element. Inspect, clean, or replace as required.

Foam density sensor: The AFFF sensor uses a small light emitting diode-phototransistor pair to measure the density of the foam in the sensor tube. If the transparent sensor tube becomes occluded with deposits of dirt, oil, or alga growth, the foam density sensor will produce a false reading. If the maintenance alarm comes on, check the sensor tube for cleanliness. The interior surfaces of the sensor tube can be cleaned with a soft, clean cloth after removing the top cap. Do not use any solvents or abrasives to clean either the interior or exterior of the sensor tube.

APPENDIX A

PARTS LIST FOR AFFF SENSOR SYSTEM

Parts list for one foam sensor \system

Item #	Description	Quantity	units	Supplier	Supplier P/N	unit price,$	total cost	Sum
1	tube, 3 " O.D., clear PVC	2	ft	RyanHerco	4000H-030	12.12	24.24	
2	tube, 1 1/2" " O.D., clear PVC	1	ft	RyanHerco	4000H-020	3.96	3.96	
3	hub reducing bushing, spg x slip, 3" x 1 1/2", white PVC (Spears D-2665)	1	ea	McMaster	2389K56	4.38	4.38	
4	tee, 1 1/2" slip, clear PVC	1	ea	RyanHerco	4001-020	16.91	16.91	
5	reducing side branch tee, 1 1/2" slip x 1 1/2" slip x 3/4" MPT	1	ea	RyanHerco	3402-248	1.84	1.84	
6	reducing bushing, 1 1/2" slip x 1/4" FPT (drain)	1	ea	RyanHerco	3438-209	0.71	0.71	
7	reducing bushing, 1 1/2" slip x 1/2" FPT (float switch)	1	ea	RyanHerco	3438-209		0	
8	sample tube cap, custom machined PVC	1	ea	local		120		
9	reducing bushing, 3/4 MPT x 1/4 FPT (air stone adapter)	1	ea	RyanHerco	3439-098	0.44	0.44	
10	pipe nipple, 1/8" pipe, 3" long, PVC	1	ea	local		1	1	
11	air stone	1	ea	Pet store		1	1	
12	air pump, 5600 cc/min at 3 psi, 120 VAC, 3/16" connections	1	ea	Pet store	MAXIMA	19	19	
13	air check valve	1	ea	Pet store		1	1	
14	air bypass valve	1	ea	Pet store		0.5		
15	M-5000/220 smart sensor kit	1	ea	MASSA	200504-501	550	550	
16	M-5000 communications adapter	1	ea	MASSA	7868-1	75	75	
17	photo-electric sensor pair, dark ON, 24 VDC	1	pair	OMRON	E3T-ST12	89	89	
18	air control valve, 4-way, 120 VAC, 1/4" NPT(F)	1	ea	ASCO	8340G1	122	122	
19	water inlet control valve, 3-way universal, 120 VAC, 1/4" NPT(F)	1	ea	ASCO	8320G176	81.5	81.5	
20	water drain control valve, 2-way, NO, 120 VAC, 1/4" NPT(F)	1	ea	ASCO	8362G264	68.19	68.19	
21	lamp holder	2	ea	NEWARK	50F6200	7.62	15.24	
22	amber lens	1	ea	NEWARK	50F6214	2.46	2.46	
23	red lens	1	ea	NEWARK	50F6212	2.46	2.46	
24	on/off switch, DPDT	1	ea	NEWARK	41F522	4.07	4.07	
25	fuse holder	1	ea	NEWARK	27F779	2.51	2.51	
26	lamps, 120 VAC T-2 base (120 PSB)	2	ea	NEWARK	96F5668	1.23	2.46	
27	programmable logic controller, IDEC Micro-3, FC2A-C24A1	1	ea	NEWARK	91F5727	451.02	451.02	
28	relay socket, 11 pin, DIN rail mount	1	ea	NEWARK	96F3913	7.35	7.35	
29	relay, 3PDT, 120 VAC	1	ea	NEWARK	91F5548	22.31	22.31	
30	relay, DPDT, 120 VAC	3	ea	NEWARK	91F5540	19.19	57.57	
31	relay socket, 8 pin, DIN rail mount	2	ea	NEWARK	50F8548	5.94	11.88	
32	terminals,feed through, DIN mount,	2	ea	NEWARK	52F9817	1.29	2.58	
33	DIN mounting rail	1	pkg	NEWARK	96F6501	2.38	2.38	
34	terminal strip, 2 rows of 12	2	ea	NEWARK	14F2603	1.69	3.38	

35	terminal strip, 2 rows of 6	2 ea	NEWARK	14F2606	2.89	5.78
36	assorted colored hook-up wire, 18-20 gage	1 ea	local		20	20
37	solderless terminals, stud size 4, box of 100	1 box	NEWARK	31N518	7.2	7.2
38	elbow, 3/8" x 3/8" hose barb	2 ea	RyanHerco	0710T-020	0.53	1.06
39	adapter, 1/4" NPT to 3/8 hose	3 ea	RyanHerco	0700T-162	0.3	0.9
40	nipple, close, 1/4" NPT	1 ea				0
41	tee, 3/8" x 3/8" hose barb	1 ea	RyanHerco	0715T-020	0.57	0.57
42	connector, 3/8" hose by 3/8" hose	6 ea	RyanHerco	0705T-020	0.28	1.68
43	adapter, 1/4" NPT x 1/8" hose barb	4 ea	RyanHerco	0700T-160	0.29	1.16
44	elbow, 1/4" NPT x 1/8" hose	2 ea	RyanHerco	0710T-160	0.29	0.58
45	tee, 1/8" hose	1 ea	RyanHerco	0715T-005	0.52	0.52
46	hose clamps, plastic, for 3/8" I.D. hose (1/2" O.D.)	12 ea	RyanHerco	0925-007	0.62	7.44
47	tubing, flexible, polyurethane, 3/8"	3 ft	RyanHerco	0585-108	1.49	4.47
48	tubing, flexible, polyurethane, 1/8"	3 ft	pet store		2.49	7.47
49	Enclosure, wall mounted, single door, PVC, 36"H x 20"W x 8"D	1 ea	Qube	HC362008	252	252
50	Range sensor target, 3" diameter sytrofoam ball	1 ea	Craft store		0.25	0.25
						1958.92

APPENDIX B

LADDER LOGIC DIAGRAM FOR THE PROGRAMMABLE LOGIC CONTROLLER

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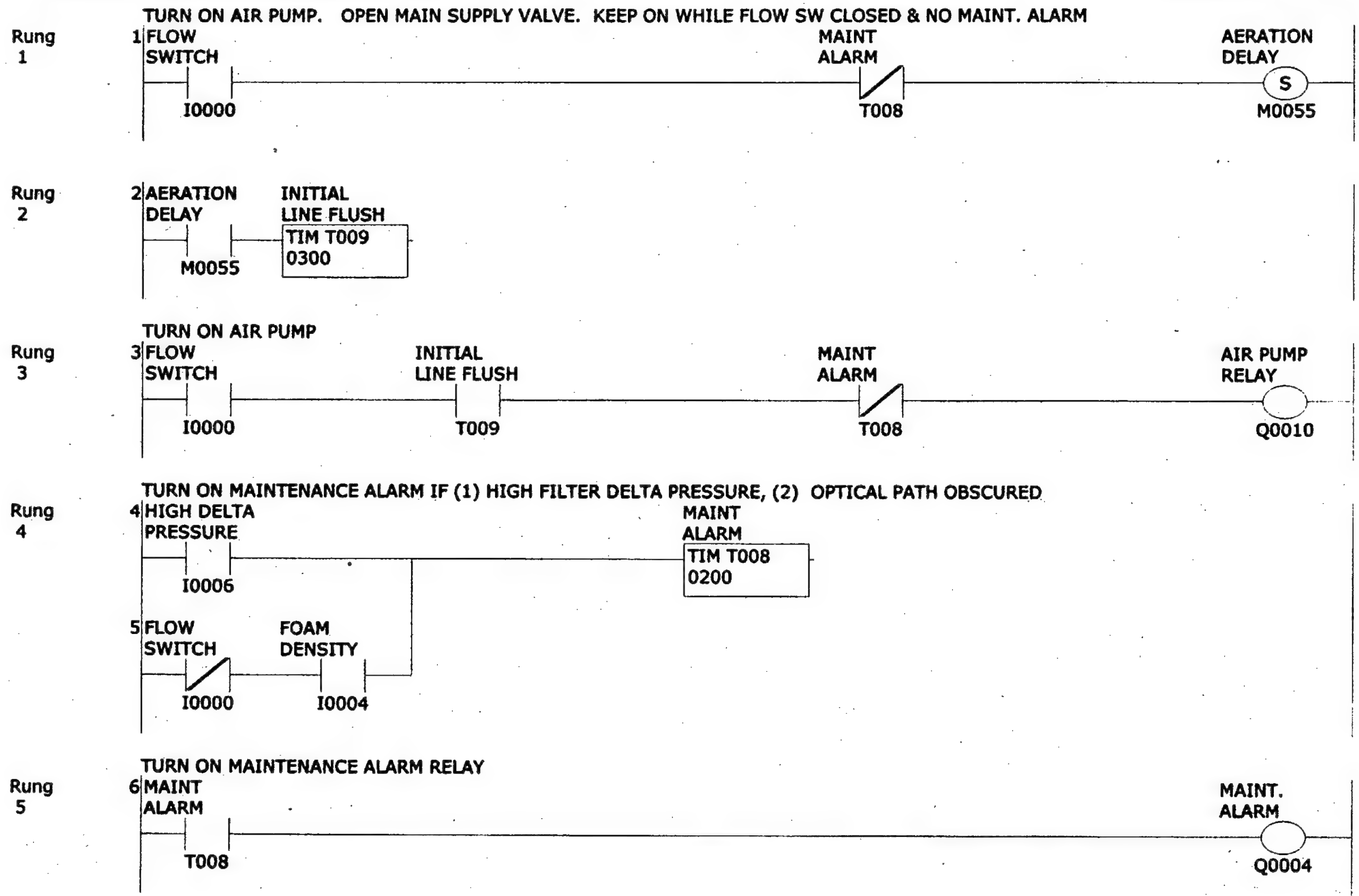

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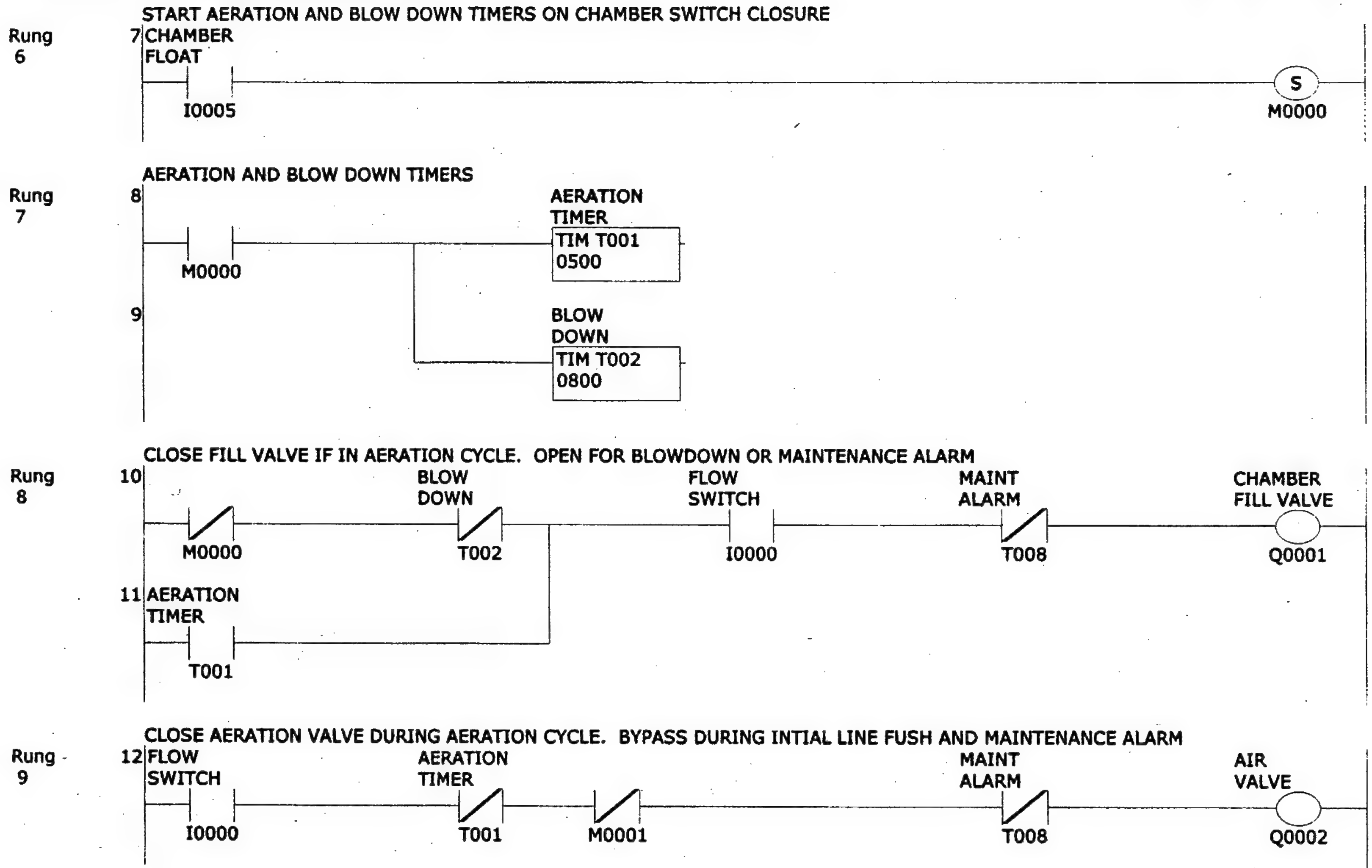

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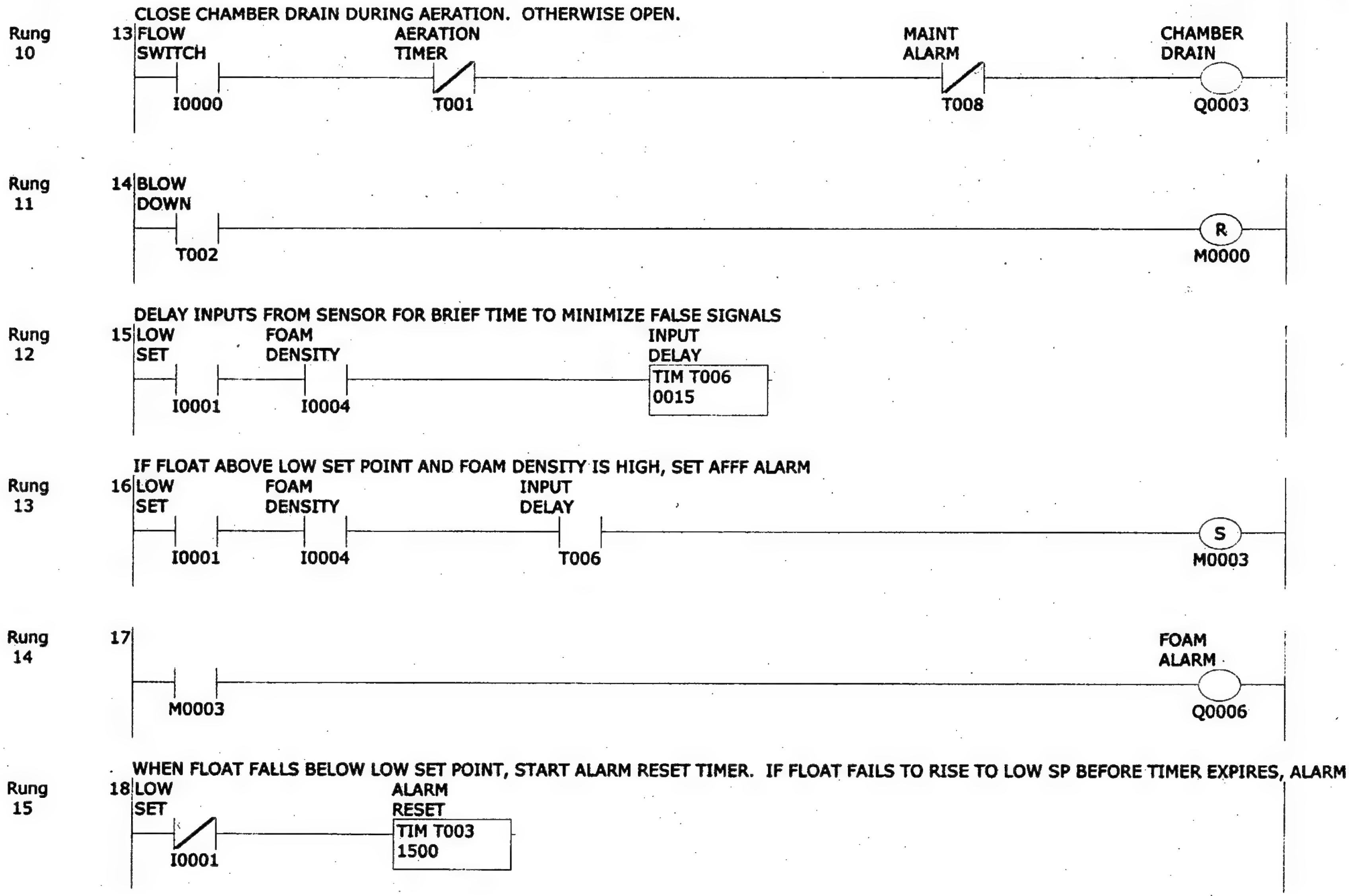
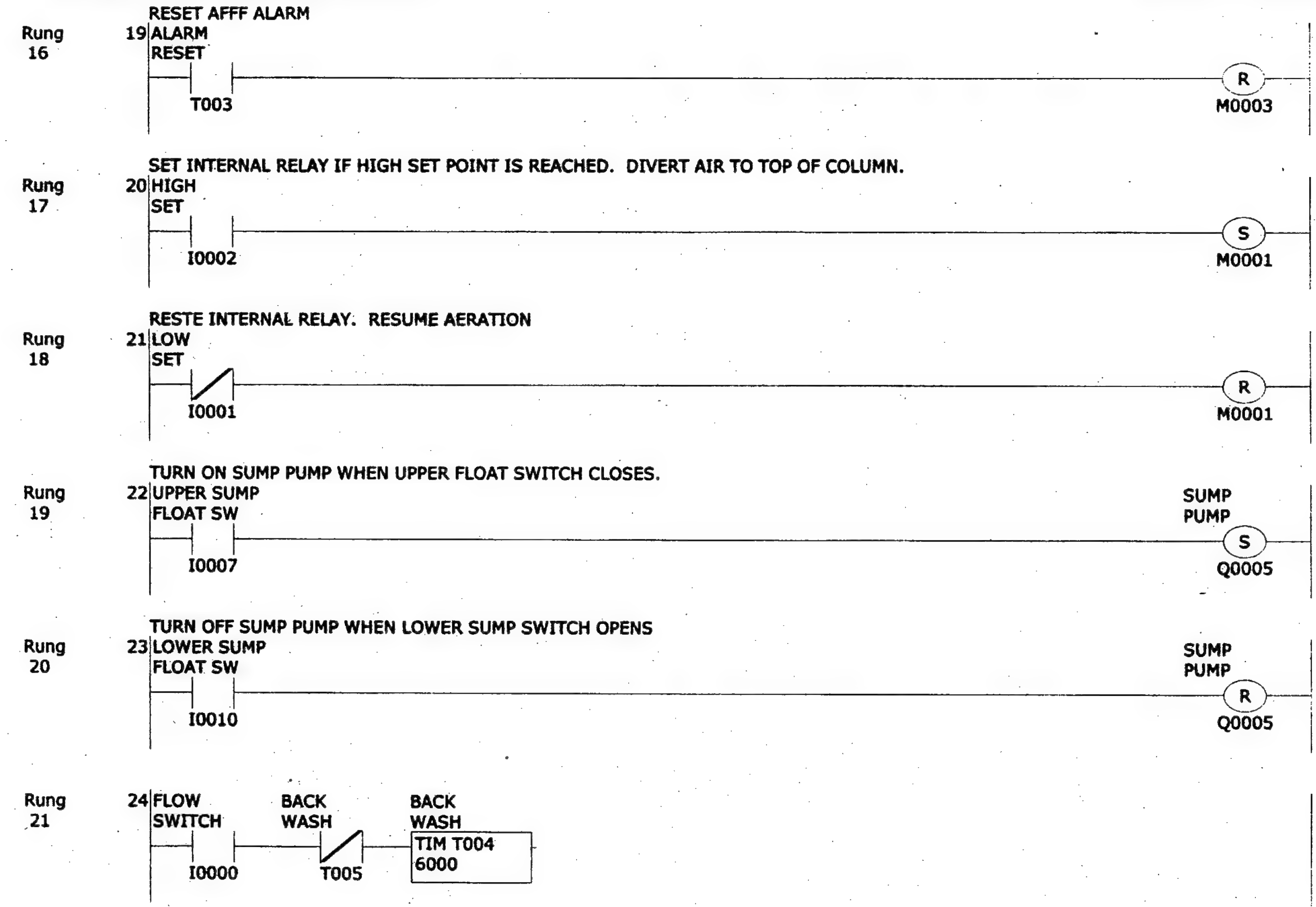
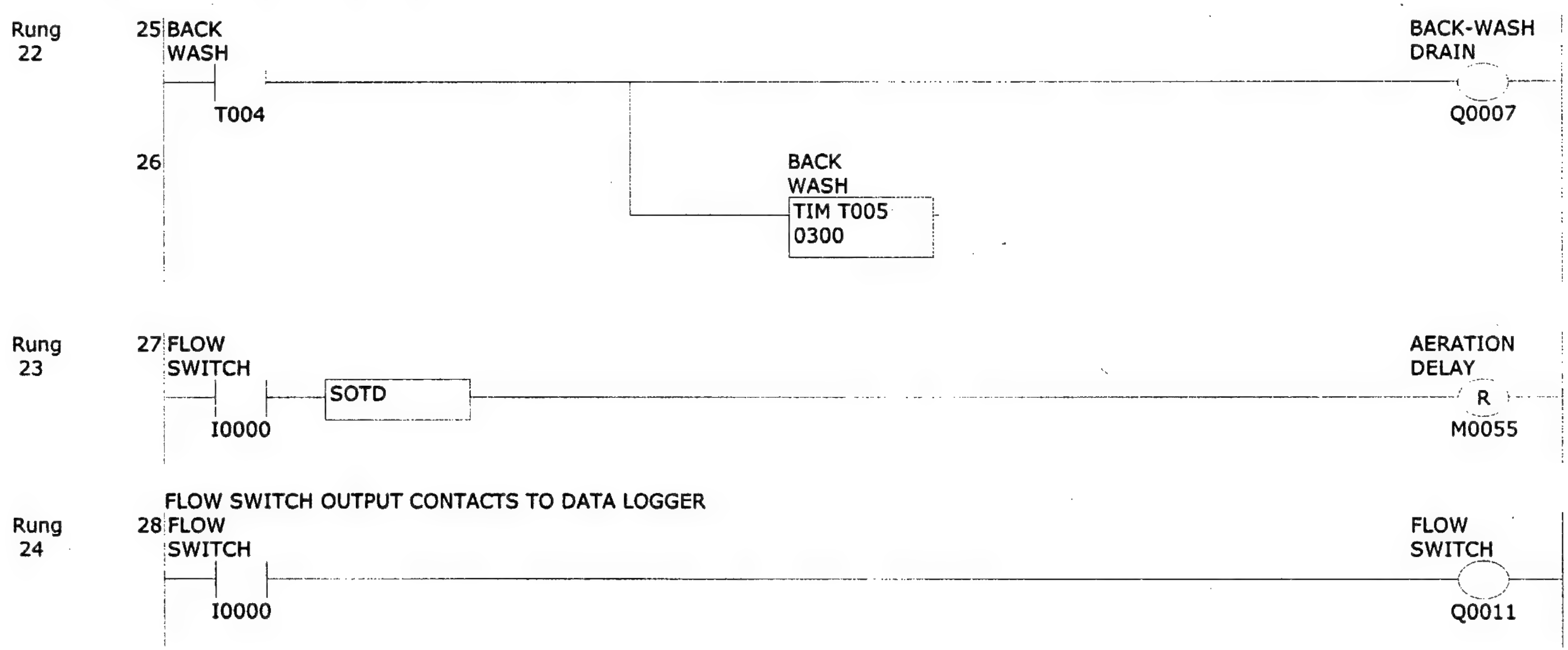



Rung 16
RESET AFFF ALARM
19 ALARM RESET
T003
R
M0003
Rung 17
SET INTERNAL RELAY IF HIGH SET POINT IS REACHED. DIVERT AIR TO TOP OF COLUMN.
20 HIGH SET
I0002
S
M0001
Rung 18
RESTE INTERNAL RELAY. RESUME AERATION
21 LOW SET
I0001
R
M0001
Rung 19
TURN ON SUMP PUMP WHEN UPPER FLOAT SWITCH CLOSES.
22 UPPER SUMP FLOAT SW
I0007
SUMP PUMP
S
Q0005
Rung 20
TURN OFF SUMP PUMP WHEN LOWER SUMP SWITCH OPENS
23 LOWER SUMP FLOAT SW
I0010
SUMP PUMP
R
Q0005
Rung 21
24 FLOW SWITCH
I0000
BACK WASH
T005
BACK WASH
TIM T004
6000

C:\PROGRA~1\IDEC\WINDLDR\STRAIN1.LDR Wed Mar 07 11:25:51 2001



APPENDIX C

M-5000 ULTRASONIC RANGE SENSOR SETTINGS

1 Current Loop Output Settings

0 mA Distance:	13 inches
20 mA Distance:	4.5 inches
OUTPUT Span:	0-20 mA
No Echo OUTPUT Current	20 mA

2 Setpoint Output Settings

Close Setpoint Distance	7 inches
Far Setpoint Distance	9 inches

	Average Distance			
	< Close Setpoint	Midzone	> Far Setpoint	No Echo
Setpoint OUTPUT A:	ON	ON	OFF	ON
Setpoint OUTPUT B:	ON	OFF	OFF	ON

Hysteresis for OUTPUT B: 2%

3 Echo Status Output Settings

Echo Status OUTPUT with NO Echo	ON	No Echo Time Out	1 Samples

4 Sampling Settings

Trigger Mode	Internal	Sample Rate	8
Average Type	Rolling	Average	4

APPENDIX D

PARTS LIST FOR OIL-WASTE SEPARATOR SYSTEM

Parts list for one strainer/filter type oil-water separator system

Item #	Description	Quantity	units	Supplier	Supplier P/N	unit price, $	total cost, $
1	Backwash water filter, 1/2" NPT fittings	1	ea	McMaster	5159K21	203.56	203.56
2	Filter housing, polypropylene	1	ea	McMaster	44195K11	37.84	37.84
3	Filter element, pleated cellulose	1	ea	McMaster	4422K6	3.13	3.13
4	Solenoid valve, NC, 120 VAC, 1/2" NPT	1	ea	ASCO	8263G210	73.62	73.62
5	centrifugal pump, 5.5 GPM @ 13.5 ft of head, 120 VAC (sump pump)	1	ea	RyanHerco	63005-200	93	93
6	Differential pressure switch	1	ea	Omega	PSW-184	84	84
7	Flow switch - 0.10 GPM, 1/2" fittings	1	ea	RyanHerco	6957-001	22.1	22.1
8	Sump container, 5 gallons	1	ea	RyanHerco	7642-500	13.85	13.85
9	Switch, float, horizontal, 1/2" NPT	2	ea	RyanHerco	6907-106	21	42
							573.1